

First Results of Aura MLS Cloud Measurements

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THE MLS CLOUD MEASUREMENT

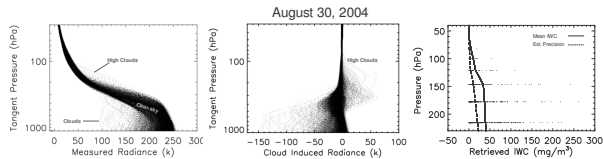


FIG 1. Left: Aura MLS 240 GHz radiances measured on August 30, 2004; Middle: The computed cloud induced radiances (ΔT_{CR}), defined as measured radiances subtract modeled radiances using the retrieved atmospheric state; Right: The retrieved cloud ice water content (IWC). Solid line is global mean profile, dashed line is estimated precision, and dots are individual samples. The values of ΔT_{CR} are produced by MLS Level 2 version 1.46 and the values of IWC are from the newer version (test 6 before version 1.5).

Retrieval of MLS cloud measurements are divided into two steps: First, cloud induced radiance (ΔT_{CR}) is obtained by calculating the difference between the measured radiance and the modeled clear-sky radiance using the retrieved atmospheric state; Second, high-altitude (215-68 hPa) cloud ice water content (IWC) is retrieved from ΔT_{CR} based on the ΔT_{CR} -IWC relations according to Wu and Jiang, [2004]. This two-step approach is illustrated in FIG 1, where MLS measurements for one day (August 30, 2004) are shown. The radiance and ΔT_{CR} used for the IWC retrieval are derived from the 240 GHz radiometer spectral band 33, channel 4 (which is a "window-channel") measurement. Without clouds, the clear-sky radiances generally increase with decreasing tangent height and can become saturated when air absorption is strong. For frequencies away from the emission lines (i.e. at window-channels), the dry and water vapor continua are the dominant sources for limb radiances. Variability of these window-channel clear-sky radiance profiles is determined mostly by the relative humidity of the atmosphere. In the presence of clouds, the limb radiances appear brighter than the clear-sky limit at high tangent heights when the background air is optically-thin, or darker at low tangent heights when the background air is optically-thick. These ΔT_{CR} s due to clouds are identified as out-liners from the clear-sky radiances, and they are best detected at either high or low tangent heights. At the transition tangent heights, clear and cloudy skies are difficult to distinguish, which unfortunately leaves a gap for cloud detection with the limb sounding. In the current MLS version 1.4/1.5 software, upper tropospheric IWC amounts between 215 hPa and 46 hPa are retrieved from the ΔT_{CR} .

CLOUD OCCURRENCE FREQUENCY (%)

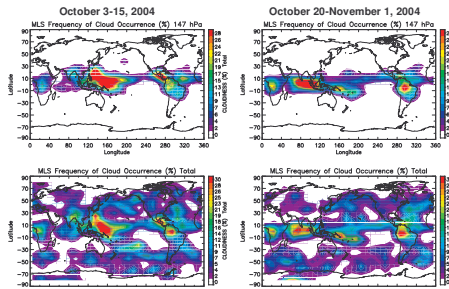


FIG 3. The cloud occurrence frequency for clouds at 147 hPa (top panel) and for total clouds (lower panel) during two time periods of October 3-15 2004 (left panel) and October 20-November 1, 2004. Note the morphology of clouds is different.

The cloud occurrence frequency is defined as the ratio of total clouds detected over the total number of samples. It tells us how frequently clouds are formed. Evolution of high-altitude cloud occurrence frequency reflects changes in regional weather and climate.

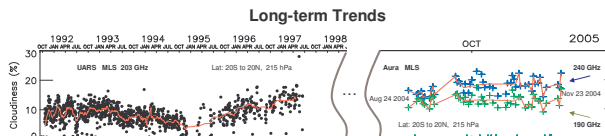


FIG 4. Time series of cloud occurrence frequency in the tropics (Lat: 20°S to 20°N) at 215 hPa, measured by UARS MLS 203 GHz radiometer during 1991-1997 and by Aura MLS 190 GHz radiometer and 240 GHz radiometer between August and November, 2004.

Time series of upper tropospheric cloud occurrence frequency may reflect variations of large scale dynamics and long-term climate change. From previous UARS MLS observations, we have found a declining trend of MLS 203 GHz tropical upper tropospheric cloudiness in the 1991-1994 time period and an increasing trend later in 1994-1997. Aura MLS will continue the monitoring of long-term trends for upper tropospheric cloudiness.

ABSTRACT

The Aura Microwave Limb Sounder (MLS) cloud induced radiance (ΔT_{CR}) and upper tropospheric cloud ice water content (IWC) measurements are made simultaneously with water vapor (H_2O) and temperature measurements. This important capability, unique to MLS, provides valuable new data for quantifying processes affecting the water budget in the upper troposphere and lower stratosphere and its potential effect on climate change. Interactions between clouds and anthropogenic pollution could also be investigated with MLS cloud measurements in the polluted areas.

CLOUD INDUCED RADIANCE (K)

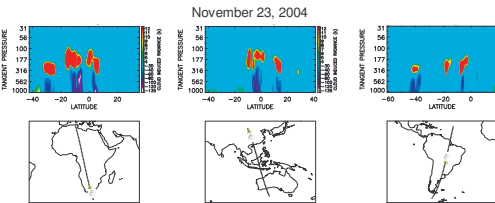


FIG 2. "Curtain" plots of Aura MLS measured 240 GHz cloud induced radiances along a section of three different orbits over Africa, maritime continents and South America on November 23, 2004.

CLOUD ICE WATER CONTENT (mg/m³)

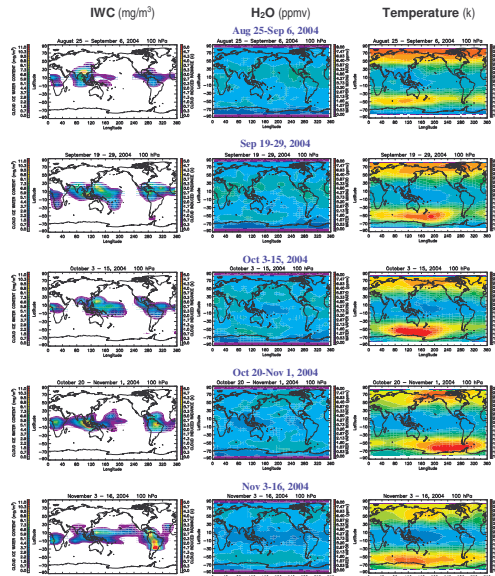


FIG 5. Comparison of 10-day mean Aura MLS IWC, H_2O and Temperature maps at 100 hPa during five different measurement periods since August 25, 2004.

FIG 5 shows evolution of 100 hPa IWC, water vapor volume mixing ratio, and temperature during the fall of 2004. In particular, we can see here the transition from a northern hemisphere summertime convective pattern to a wintertime pattern --- convection occurring primarily over Asia, Africa, and Central America, as well as transitions to a regime with some continental convection and intense convection over the oceanic Western Pacific.

The interplay between these quantities is complex and a clear picture of the underlying mechanisms has not yet appeared, reflecting the present debate in the field whether air entering the stratosphere is dehydrated during vertical transport in convection [e.g. Sherwood & Dessler, 2000] or during horizontal transport through cold regions [e.g. Holton and Gettelman, 2001], or some combination of the two. It is likely that Aura MLS, with its ability to provide information on water vapor, clouds, and temperature simultaneously, will help us identify the important processes occurring around the tropopause.

COMPARISON WITH OTHER SATELLITE AND METEOROLOGICAL DATA

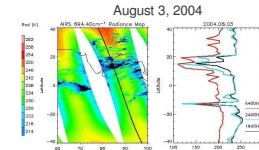


FIG 6. The left image shows AIRS radiances from a channel sensitive to the upper troposphere. Low radiance values indicate upper tropospheric clouds. The black line is the MLS measurement track during that day. The right panel shows MLS low-altitude radiances at 190, 240 and 640 GHz, which have different sensitivities to cloud particle sizes.

FIG 7 on the right shows comparisons among the MLS cloud measurement, the AIRS cloud data, the precipitation map derived from the NOAA Climate Prediction Center Merged Analysis of Precipitation (CMAP), and the NASA Goddard Meteorology Assimilation Office (GMAO) outgoing longwave radiation (OLR). All maps show values averaged over the ten Aura MLS measurement days between September 19 and 29, 2004.

The morphological agreement between MLS and AIRS is acceptable especially considering that the two instruments have different sensitivity to clouds. MLS measures larger ice amounts that saturate shorter-wavelength techniques.

The CMAP data blends station rain gauge observations and five different types of satellite products to estimate global precipitation amounts. Both the CMAP and OLR are good indicators of deep convection. During late September, 2004, the OLR and CMAP rainfall field still exhibit two convective outflow centers (leftover from the summer monsoon season) about 10° north of the equator over south Asia and Central America, which are also the areas of high cloudiness. In addition, convective activities start to pick up over the Western Pacific, maritime continent and equatorial Africa, where the upper tropospheric clouds are forming.

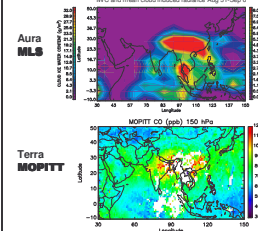


FIG 8. MSL 147 hPa IWC map (top panel) and MOPITT 150 hPa CO map (lower panel), both averaged during late August and early September.

FIG 8 shows both the IWC map from Aura MLS and the CO mixing ratio map from the Measurements of Pollution In The Troposphere (MOPITT) onboard Terra. The missing data on MOPITT's map are consistent with cloudy areas detected by MLS. The enhancement of CO around the southern and southwestern China is apparently associated with clouds in the same region/time, which might indicate a possible connection between anthropogenic pollution and high-altitude cloud formation in the region.

The Aura MLS cloud data are in general fairly consistent with other satellite measurements and meteorological data.

FIG 6 on the left compares radiances measured by the Aura MLS and by the Atmospheric Infrared Sounder (AIRS) on board Aqua during August 3, 2004, the first full day of MLS operation on Aura. This shows the value of NASA's satellite "A-Train", where data from Aura and Aqua provide more information together than can be obtained from either alone.

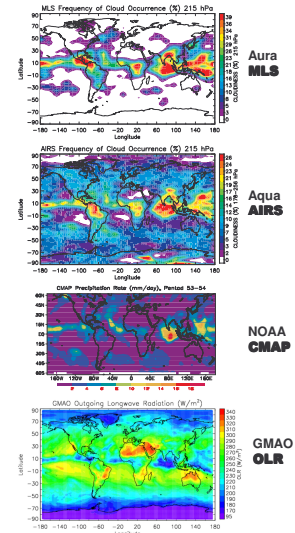


FIG 7. Morphological comparisons among the cloud occurrence frequency from Aura MLS (top panel), the cloud occurrence frequency from Aqua AIRS (second panel), the CMAP precipitation (third panel), and the GMAO OLR (fourth panel). All maps are averaged over ten MLS measurement days between September 19 and 29, 2004.

ACKNOWLEDGEMENTS

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